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County socioeconomic characteristics and pediatric renal transplantation outcomes

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Abstract

Background—Existing risk adjustment models for solid organ transplantation omit socioeconomic status (SES). With limited data available on transplant candidates' SES, linkage of transplant outcomes data to geographic SES measures has been proposed. We investigate the utility of county SES for understanding differences in pediatric kidney transplantation (KTx) outcomes.

Methods—We identified patients < 18 years of age receiving first-time KTx using United Network for Organ Sharing registry data in two eras: 2006–2010 and 2011–2015, corresponding to periods of county SES data collection. In each era, counties were ranked by 1-year rates of survival with intact graft, and by county SES score. We used Spearman correlation (ρ) to evaluate the association between county rankings on SES and transplant outcomes in each era and consistency between these measures across eras. We also evaluated the utility of county SES for improving prediction of individual KTx outcomes.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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Results—The analysis included 2972 children and 108 counties. County SES and transplant outcomes were not correlated in either 2006–2010 ($\rho = 0.06$; $p = 0.525$) or 2011–2015 ($\rho = 0.162$, $p = 0.093$). County SES rankings were strongly correlated between eras ($\rho = 0.99$, $p < 0.001$), whereas county rankings of transplant outcomes were not correlated between eras ($\rho = 0.16$, $p = 0.097$). Including county SES quintile in individual-level models of transplant outcomes did not improve model predictive utility.

Conclusions—Pediatric kidney transplant outcomes are unstable from period to period at the county level and are not correlated with county-level SES. Appropriate adjustment for SES disparities in transplant outcomes could require further collection of detailed individual SES data.

Keywords

Kidney transplant; Transplant outcomes; Socioeconomic status; UNOS; United Network for Organ Sharing

Introduction

Despite improving rates of graft and patient survival, solid organ transplantation remains a complex and risky procedure, with 5-year mortality rates ranging from less than 3% for pediatric kidney transplantation (KTx) to 45% for lung transplantation in patients aged 12 and older [1, 2]. In the USA, patients register for a transplant to be performed at a specific center, and are subsequently considered for donor organs that become available in that area [3]. Patients are permitted to register at multiple centers, and are then considered for organs in the surrounding areas of these centers [3]. Patients may also be considered for organs on a regional or national level if there are no local matches for these organs [3]. Transplant centers that fail to meet performance requirements on risk-adjusted transplant outcomes can be penalized by the Centers for Medicare & Medicaid Services (CMS) [4, 5]. Therefore, accurate prediction of transplant outcomes that accounts for differences outside of centers' control is essential for fair assessment of center performance. Risk-adjusted transplant outcomes are calculated based on information contained in the national transplant registry. Patients undergo follow-up with the team involved in their transplant, and mandatory data reporting to the national registry continues even if a transition of care occurs, such as the transition from pediatric to adult care.

An ongoing criticism of existing risk adjustment models in transplantation is the omission of socioeconomic status (SES), which strongly predicts health care access and outcomes across a wide variety of patient populations and surgical procedures [4, 6–8]. Problematically, the US national transplant data required reporting of very little data on individual SES. This limitation is especially relevant in pediatric transplantation, where patients' own employment status and educational attainment are not informative of their SES; children's health insurance coverage is confounded by more generous thresholds for Medicaid eligibility, compared to adults, and special Medicare eligibility is available for children undergoing KTx. To overcome the limitations of reported data on transplant recipients' individual SES, several groups have advanced the use of contextual or geographic measures of SES for predicting transplant outcomes [9–13]. Specifically, measures of geographic SES may account for the effects of both individual and community socioeconomic characteristics

on transplant outcomes [14]. In the present study, we focus on pediatric KTx as the setting where risk adjustment for geographic SES may be especially useful, due to the lack of valid individual-level SES data. In this setting, we explore the potential utility of including county characteristics in risk adjustment models for KTx outcomes. Specifically, we examine whether measures of county SES disadvantage correspond to poor county-specific outcomes of pediatric KTx, and whether county rankings on SES and KTx outcomes are generally stable over time. Next, we aim to determine whether including county SES rankings in an individual-level model improves prediction of pediatric KTx outcomes.

Methods

The study was exempted from review by the local Institutional Review Board as it was not human subject research, since it involved the secondary analysis of a de-identified registry. Data on children (age < 18 years) receiving first-time, isolated single or bilateral KTx were obtained from the United Network for Organ Sharing (UNOS) registry spanning the years 2006 to 2015, with follow-up through 2016 [15]. The UNOS registry contains information on all transplants performed in the USA, and mandatory data reporting to the registry continues even if a transition of care occurs. Patients' county of residence was identified based on their ZIP code at the time of surgery. For ZIP codes spanning multiple counties, the ZIP code was assigned to the county in which most of its population resided as of the 2010 US Census. Socioeconomic and demographic information for each county was obtained from the US Census Bureau, with 5-year estimates from the American Community Survey (ACS) used to define county SES in 2006–2010, and, separately, in 2011–2015 [16]. Patients with unknown place of residence and patients living in counties where < 5 residents received a pediatric KTx during either time period were excluded from the analysis [12]. County socioeconomic characteristics and patient characteristics were compared between counties included in the study and counties excluded due to low pediatric KTx volume.

To compare transplant outcomes against a contemporaneous measure of county SES, patients were divided according to year of transplant in 2006–2010 or 2011–2015. For each time period, counties were ranked by 1-year rates of patient survival with functioning graft, determined using the Kaplan-Meier method. Neighborhood disadvantage was measured by a composite SES score developed by Diez Roux et al. [17, 18]. This measure summed the Z scores of 6 county-level variables extracted from the ACS: log median household income; log median value of housing units; percentage of households receiving interest, dividend, or net rental income; percentage of adults 25 years of age or older who had completed high school; percentage of adults 25 years or older who had completed college; and percentage of employed people 16 years of age in executive, managerial, or professional specialty occupations (in later ACS rounds, changed to management, business, science, and arts occupations). Counties included in the study were separately ranked by their SES score in each era (2006–2010 vs. 2011–2015). For the county-level analysis, we calculated Spearman's correlation coefficient (ρ) between the rankings of the 1-year KTx outcomes and the SES score for each of the two eras. We also calculated Spearman's correlation coefficient between the two eras for each type of ranking (SES and KTx outcomes).

Next, we sought to determine whether inclusion of county SES rank (categorized into quintiles) would improve prediction of patient outcomes in individual-level models. For this analysis, we constructed a multivariable logistic regression model of survival to 1 year with a functional graft, adjusting for patient, donor, and procedural characteristics. Patient characteristics included age, gender, race (white, black, or other), body mass index (BMI), public insurance, time on dialysis, and time on wait list. Donor characteristics included age, donor status (living or deceased), and human leukocyte antigen (HLA) mismatch level. Procedural characteristics included graft cold ischemia time. In this analysis, we excluded patients with missing covariate data and patients whose vital status was not reported within 30 days of the first transplant anniversary, except for patients known to have previously died or to have experienced graft failure. To evaluate improvement in model predictive utility, we compared the area under the receiver operating characteristics curve (AUC) between the model including only patient-, donor-, and procedure-specific covariates and a second model adding county SES quintile. We also fitted a Cox model of time to graft failure or mortality, adjusting for the covariates above, and adding a shared frailty term to represent residual differences in outcomes among counties that were not explained by differences in county SES [12]. For the Cox model, we expanded the analysis to include patients who resided in counties with three or more transplants throughout the study period. Counties with one or two patients were excluded because the patient count was too low to estimate the shared frailty term. Statistical analysis was performed using Stata/IC 14.2 (College Station, TX: StataCorp, LP), and $p < 0.05$ was considered statistically significant.

Results

The UNOS registry contained information for 5953 patients aged < 18 years who received a first-time, isolated KTx between the years 2006–2015. Pediatric kidney transplants were performed at 169 centers and involved residents of 1300 counties, with each center serving residents of 1 to 51 counties. We excluded 55 patients with an unknown place of residence and 2826 patients from counties where < 5 children received KTx in either era of the study period. Patients excluded from the analysis due to residence in a county with a low volume of KTx were predominantly white and were more likely to reside in counties with lower SES scores.

Among the remaining 2972 patients, 1519 underwent transplants in 2006–2010 and 1453 underwent transplants in 2011–2015. Patient characteristics in each era are summarized in Table 1, and the Kaplan-Meier plots of survival with intact graft are shown for each era in Fig. 1. Considering demographic characteristics, patients in the later era tended to be younger than patients in the earlier era, but distributions of gender, race, insurance coverage type, and wait list time were similar between the two eras. The multivariable logistic regression analysis of individual-level outcomes, described below, included 2537 patients with complete covariate data and known vital status at 1 year post-transplant.

In total, the study cohort included residents of 108 counties. Characteristics of counties are summarized by quintile of the composite SES score in Supplemental Table 1. Differentiating counties by SES score revealed large differences in income and wealth between the lowest- and highest-ranked counties. For example, median household income was 75% greater in the

highest-SES counties as compared to the lowest SES counties. Interestingly, comparison of patients in each era (Table 1) revealed that transplants in the latter era included fewer patients from counties in the lowest two quintiles of SES. However, 1-year survival with intact graft did not necessarily follow the gradient of county SES. In each of the two transplant periods, median rates of 1-year survival with intact graft in each SES quintile were at least 90% in all SES quintiles, and the 25th percentile of 1-year survival with intact graft was lowest in counties from the middle SES quintile (Supplemental Table 1). In further county-level analysis, county SES rankings were not correlated with county KTx outcomes for the eras 2006–2010 ($\rho = 0.06$, $p = 0.525$) or 2011–2015 ($\rho = 0.16$, $p = 0.093$). County rankings by SES were strongly correlated between the two eras ($\rho = 0.99$, $p < 0.001$), but county rankings by KTx outcomes were not correlated between eras ($\rho = 0.16$, $p = 0.097$).

When modeling individual-level survival to 1 year with a functional graft (Table 2), county SES was not associated with KTx outcomes, and did not improve the model's predictive utility (AUC = 0.66 with SES quintile vs. AUC = 0.65 without, $p = 0.451$). Public insurance coverage, the only measure of individual-level SES, was also not significantly associated with 1-year outcomes. When disaggregating the individual-level analysis by era, the SES quintile was still not associated with 1-year outcomes (Supplemental Table 2). Incorporating the county SES quintile did not improve the model's predictive ability for era 1 (AUC = 0.70 with SES quintile vs. AUC = 0.69 without, $p = 0.266$), but it did improve the predictive ability for era 2 (AUC = 0.69 with SES quintile vs. AUC = 0.62 without, $p = 0.036$). When fitting the shared frailty Cox model of time to graft failure or mortality for individuals living in counties with at least three transplants during the study period, we were able to increase the sample size to 4192 patients from 448 counties. Nevertheless, there remained no association between SES quintile and the hazard of the study outcome (graft failure or mortality; Table 3). The shared frailty term was not statistically significant ($p = 0.498$), implying there were no residual differences across counties after accounting for other characteristics.

Discussion

SES has been shown to predict patient outcomes across a wide variety of patient populations and surgical procedures. This has sparked interest in adding SES measures to models of surgical outcomes [19]. In the case of solid organ transplantation, limited individual SES data in the UNOS registry has posed an obstacle to incorporating SES into risk-adjustment models. One strategy to overcome this limitation is to use geographic SES measures [9]. However, studies on the contribution of geographic SES to transplant outcomes have showed mixed results. In the case of heart transplantation, outcomes varied by block group SES in the USA, but not by county SES [10, 12]. In the case of KTx, poverty measured at the ZIP code level was not correlated with adverse transplant outcomes in one US study [13]. Community poverty has been linked to lower access to KTx [20, 21], but a recent study found no association between SES at ZIP code level and either the likelihood of undergoing transplantation or risk of death on the wait list among children listed for KTx [22]. A number of studies have also examined the association between community SES and transplant outcomes in Europe. KTx outcomes varied by a neighborhood-level social deprivation index in England and Wales but not in Ireland [23–25], and did not vary by SES

measured at a postal code level in Scotland or the Netherlands [26, 27]. Given the uncertain utility of SES for predicting transplant outcomes, our study adds an important null finding for pediatric KTx, where a composite measure of county SES was not correlated with 1-year outcomes at either the county or the individual level in the USA. Characteristics of the US health system, such as variability in insurance coverage, may make the use of community SES for transplant risk adjustment less informative than in Europe.

Considering previous studies of geographic influences on transplant outcomes in the USA, these mixed results are possibly explained by inconsistent definitions of geographic areas. In the USA, block groups are the smallest unit defined by the Census Bureau, averaging a population of 1000 and intended to represent relatively homogeneous groups of people [28]. Areas such as ZIP codes, however, have an average population of 30,000 and are not based on political or Census boundaries, implying greater heterogeneity in residents' social and clinical risk factors [28]. As this heterogeneity increases in larger areas such as counties and states, it may weaken the relationship between geographic SES measures and individual clinical outcomes. Yet, in smaller areas represented by only a few transplant recipients, it becomes more challenging to demonstrate geographic variation in transplant outcomes independent of individual-level confounding factors [12]. In our study, even when we aggregated data over multiple years, most counties in the USA did not have enough pediatric KTx recipients for analysis of county differences. When examining regions smaller than counties, the number of pediatric KTx recipients decreases further, making it difficult to separate variation in risk due to community characteristics from variation in risk due to patient-level factors. Therefore, studies that appear to demonstrate differences in transplant outcomes across geographic areas containing few patients (such as postal codes) may risk capturing random variation in patient-level characteristics rather than the true impact of community-level factors. In our study, county-level KTx outcomes were challenging to estimate precisely, were inconsistent from period to period, and did not align with county SES rankings. Together with the results of our individual-level analysis, these findings suggest that county measures of SES fundamentally cannot account for variation in pediatric KTx outcomes in a consistent and replicable manner.

Due to these issues of using geographic measures to predict transplant outcomes, alternative strategies must be considered for evaluating socioeconomic disparities in transplantation. The implementation of systematic screening for social determinants of health (SDH) has been previously described in primary care settings [29, 30], and could be added to reporting requirements for transplant candidate registration. While such screening could provide accurate patient-level SES data, standardized collection of SDH in clinical settings entails its own challenges, including a lack of consensus on best measurements and data collection practices, lack of collaboration between health systems and social services organizations, and technological challenges to capturing and retaining these data [31]. However, overcoming these challenges may both enrich data collection for transplant evaluation and risk adjustment processes and benefit patients and families who could be referred to social services according to results of SDH screening. Health care teams could pursue cost-effective SDH screening using student and intern team members to collect SDH data and facilitate referral to social services [32, 33]. For socioeconomically disadvantaged patients who ultimately undergo transplantation, further research could investigate whether early

referral to social services improves later treatment adherence or resumption of usual activities.

Socioeconomic status disparities in KTx outcomes begin with disparities in access to transplantation [34–36]. Notably, psychosocial and financial factors are a major part of the assessment for transplant candidacy [37, 38]. The psychosocial assessment evaluates candidates' ability to follow the treatment plan, as well as their available social support; while the financial assessment ensures patients' resources will be sufficient for adhering to the post-transplant medication and follow-up regimens. In this context, risk adjustment for SES introduces some ethical challenges related to candidate selection. As noted above, geographic SES measures obscure heterogeneity of individual characteristics within a particular area. This heterogeneity could be exploited by listing the healthiest candidates from the lowest SES areas to attain better-than-predicted outcomes. Decision-making influenced by SES risk adjustment may contribute to previously reported disparities in transplant listing across UNOS regions and donor service areas (DSAs) [39–41]. In the US healthcare system, there are also several ethical concerns related to incorporating geographic SES measures in transplant outcome risk adjustment. Including SES in quality metrics could result in risk adjustment that incentivizes asset spend-down by patients seeking to qualify for public insurance [42–44]. With previous reports suggesting that change in insurance coverage around the time of transplant is associated with worse outcomes [45, 46], SES risk adjustment that incentivizes patients to switch insurance during this vulnerable period could have unintended consequences. Additionally, proposals to incorporate SES into transplant risk adjustment have not addressed differences in public insurance eligibility across states, or differential associations between SES and transplant outcomes across different parts of the country [47].

Our study is limited by aspects of the UNOS registry and characteristics of the pediatric KTx population. First, counties of residence were assigned on the basis of ZIP code, introducing the possibility of misclassification. Second, to capture a sufficient number of patients within each geographic area, we considered counties as the unit of analysis, rather than smaller and more homogenous geographic groups, such as census block groups or census tracts. Even with the analysis performed at the county level, many patients were excluded for residing in counties where < 5 pediatric KTx have been performed during either era of the study period. Many of these counties were more rural and had lower socioeconomic scores, which may limit the generalizability of our findings to lower population areas. The limited number of pediatric KTx performed also contributed to instability in county-specific outcomes over time, leading to weak correlations between county transplant outcome rankings and county SES rankings. This may have also been related to overall high rates of survival with a functioning graft 1 year after pediatric KTx. Finally, variable selection for the patient-level models required excluding some variables due to perfect prediction or multicollinearity, so it did not exhaustively assess the impact of all relevant clinical factors on KTx outcomes.

Despite these limitations, our study suggests that county measures of SES do not improve prediction of pediatric 1-year KTx outcomes, are not concordant with county rankings on post-transplant survival, and are not associated with the hazard of graft failure or mortality.

Although accounting for patient SES in evaluation of KTx outcomes is important, inclusion of geographic measures may be an unsatisfactory approach to this goal. To improve prediction of pediatric KTx and other solid organ transplant outcomes, future studies should evaluate the feasibility and value of prospective SDH screening of transplant candidates, harmonized across transplant centers in a way that would support nationally consistent adjustment for SES.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Fig. 1.
Kaplan-Meier rate of 1-year survival with intact graft, by era ($N = 2972$)

Table 1Characteristics of kidney transplant patients by era ($N = 2972$)

Characteristic	Era 1 (2006–2010) ($N = 1519$)		Era 2 (2011–2015) ($N = 1453$)		<i>p</i>
	<i>N</i> (%) or median (IQR)	Missing data (<i>N</i>)	<i>N</i> (%) or median (IQR)	Missing data (<i>N</i>)	
SES quintile					
Highest	236 (16%)	0	213 (15%)	0	< 0.001
2	251 (17%)		239 (16%)		
3	303 (20%)		388 (27%)		
4	360 (24%)		308 (21%)		
Lowest	369 (24%)		305 (21%)		
Recipient					
Age	13 (7, 16)	0	12 (6, 15)	0	0.002
Female	657 (43%)	0	620 (43%)	0	0.749
Race					
White	455 (30%)	0	464 (32%)	0	0.475
Black	455 (30%)		307 (21%)		
Other	726 (48%)		682 (47%)		
Body mass index	19 (17, 22)	19	19 (17, 21)	4	0.007
Public insurance	949 (62%)	0	890 (61%)	0	0.493
Time on dialysis (years)	1 (0, 2)	57	1 (0, 2)	23	0.125
Time on wait list (years)	0 (0, 1)	0	0 (0, 1)	0	0.910
Donor					
Age	23 (18, 31)	0	25 (19, 32)	0	0.001
Living	368 (24%)	0	444 (31%)	0	< 0.001
HLA mismatch level	4 (3, 5)	9	4 (3, 5)	8	0.370
Procedural					
Graft cold ischemia time (h)	10 (5, 15)	151	9 (3, 13)	81	< 0.001

HLA human leukocyte antigen, *IQR* interquartile range, *SES* socioeconomic status

Multivariable logistic regression of 1-year survival with functional graft with and without adjustment for county socioeconomic status quintile ($N = 2537$)

Table 2

Characteristic	Model 1			Model 2 with SES quintile added		
	OR	95% CI	<i>p</i>	OR	95% CI	<i>p</i>
SES quintile						
Highest				Ref.		
2				1.2	(0.6, 2.7)	0.614
3				0.6	(0.3, 1.1)	0.082
4				1.1	(0.5, 2.2)	0.828
Lowest				0.9	(0.5, 2.2)	0.828
Recipient						
Age	1.1*	(1.02, 1.1)	0.002	1.1*	(1.02, 1.1)	0.001
Female	0.9	(0.6, 1.3)	0.574	0.9	(0.6, 1.3)	0.598
Race						
White	Ref.			Ref.		
Black	0.6	(0.5, 1.4)	0.463	0.6	(0.4, 1.1)	0.093
Other	0.8	(0.5, 1.4)	0.463	0.8	(0.5, 1.4)	0.508
Body mass index	0.95*	(0.92, 0.99)	0.014	0.9*	(0.9, 0.99)	0.009
Public insurance	0.8	(0.5, 1.2)	0.318	0.8	(0.5, 1.3)	0.356
Time on dialysis	0.9	(0.8, 1.0)	0.084	0.9	(0.8, 1.0)	0.054
Time on wait list	1.0	(0.8, 1.2)	0.928	1.0	(0.8, 1.2)	0.818
Donor						
Age	1.0	(1.0, 1.0)	0.270	1.0	(1.0, 1.0)	0.274
Living	1.4	(0.7, 3.1)	0.350	1.5	(0.7, 3.3)	0.272
HLA mismatch level	0.9	(0.8, 1.1)	0.212	0.9	(0.8, 1.1)	0.245
Procedural						
Graft cold ischemia time	1.0	(1.0, 1.0)	0.361	1.0	(1.0, 1.0)	0.533

CI confidence interval, HLA human leukocyte antigen, OR odds ratio, SES socioeconomic status

* Denotes $p < 0.05$

Table 3

Cox regression of graft failure or mortality for patients receiving a kidney transplant between 2006 and 2015, for counties with three or more transplants over the study period ($N = 4192$)

Characteristic	HR	CI (95%)	<i>p</i>
SES quintile			
Highest	Ref.		
2	1.2	(1.0, 1.5)	0.083
3	1.0	(0.8, 1.3)	0.827
4	1.0	(0.8, 1.3)	0.682
5	1.0	(0.8, 1.3)	0.879
Recipient			
Age	1.1 *	(1.04, 1.1)	< 0.001
Female	1.5 *	(1.3, 1.7)	< 0.001
Race			
White	Ref.		
Black	1.9 *	(1.6, 2.3)	< 0.001
Other	0.9	(0.8, 1.1)	0.533
Body mass index	1.0	(1.0, 1.0)	0.226
Public insurance	1.2 *	(1.1, 1.5)	0.008
Time on dialysis	1.0	(1.0, 1.1)	0.101
Time on wait list	1.0	(0.9, 1.0)	0.340
Donor			
Age			
Living	0.8	(0.6, 1.1)	0.139
HLA mismatch level	1.0	(1.0, 1.1)	0.473
Procedural			
Graft cold ischemia time	1.0	(1.0, 1.0)	0.089

CI confidence interval, HLA human leukocyte antigen, HR hazard ratio, SES socioeconomic status

* Denotes $p < 0.05$